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# Osteoporosis: Awareness, Prevalence and Role of Nutrients

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***Abstract:*** Osteoporosis is a common metabolic bone disorder characterized by a decrease in bone mineral density apparently leading to increased risk of fracture. It is a clinically silent disease until it manifests in the form of fractures because it is always underdiagnosed and undertreated. It affects both men and women but women are found to be more susceptible due to number of reasons. Inorder to minimize the risk of fractures, awareness and knowledge regarding the disease and several lifestyle modifications including healthy diet, active lifestyle, regular exercise and prevention from fall, sudden strain or bumps can reduce the risk of osteoporosis and osteoporotic fractures.
***Keywords***- Osteoporosis, bone mineral density, prevalence, nutrients

**Introduction**

Osteoporosis is the common metabolic bone disorder affecting 200 million individual worldwide and is increasing significantly. It is often undertreated and under recognized because it is a clinically silent disease until it manifests in the form of fracture (NOF, 2010). Osteoporosis-related fractures are often associated with extensive pain, suffering, disability and possibly even death. Further, with increasing longevity the life expectancy of senior citizens in India is expected to increase to 71 years from 67 years at present by 2025 and to 77 years by 2050. Thus, increasing longevity and a greater proportion of the Indian population over the age of 50 years are likely to result in an increased number of people affected by osteoporosis (Khadilkar and Mandlik, 2015). Sufficient recognition of the disease is essential along with its appropriate medical and non medical treatments. Individuals who have one osteoporotic fracture are usually at increased risk for developing another osteoporotic fracture. For example, the presence of one or more vertebral fractures results in a five-fold increased risk of having another vertebral fracture. The life time risk of fractures of the hip, wrist and spine is 40 per cent. The life time risk of hip fracture for a woman is 14 per cent and it increases with age (Clynes *et al.*, 2020). Twenty per cent women have a hip fracture at 80 years and approximately, 50 per cent have it at 90 years. Women who are older than 85 years are usually 8 times more likely to be admitted to the hospital for a hip fracture than women of the age between 65 to 74 years (McDonough *et al.*, 2021). Awareness regarding osteoporosis is necessary to minimize the risk of fractures and low bone mineral density in future. Osteoporosis can be managed by thorough history and assessment of risk factors, physical examination and investigation to know the secondary causes, diagnosis and classification of the condition after estimating bone mineral density, estimation of ten year fracture risk using fracture risk algorithm (FRAX), lifestyle and diet modification and by performing pharmacological therapy. There are certain medicines that help in treating osteoporosis (Shoback *et al.*, 2020). Bone density can be naturally improved by consuming foods that contain necessary vitamins and minerals (Price *et al.*, 2012).

**General awareness about osteoporosis**

Osteoporosis is a major health concern that results in porous bones by reducing the bone density and bone strength and increasing the risk of fractures. Knowledge about osteoporosis primarily focuses upon the possible factors for the disease and the extent to which this knowledge is utilized to take preventive measures (Rafraf *et al.*, 2009). The general lack of awareness about osteoporosis in Indian women was assessed by Pande *et al*. (2009) on 73 females (average age 44.7 years) of a teaching institute using the osteoporosis questionnaire (OPQ). Findings showed that 74 per cent of the respondents defined osteoporosis correctly but general lack of awareness observed in all the other areas. Age, menopausal status, previous history of fracture and family history of osteoporosis had no influence on the level of knowledge. The source of knowledge was also gathered and it opened-up that media (74%) was the commonest source of knowledge followed by friends (49%) and doctors (25%).

Gopinathan *et al*. (2016) manifested the level of awareness in 100 women in Chandigarh using the osteoporosis health belief scale (OHBS). Seven component parameters of OHBS such as susceptibility, seriousness, benefits of exercise & calcium intake, barriers to exercise & calcium intake and health motivation found to be correlated with the bone mineral density. There was no statistically significant difference observed between the parameters and incidence of occurrence of osteoporosis (p values 0.804, 0.520, 0.293, 0.329, 0.760, 0.953 and 0.859, respectively). The results also show that there is a great deficit in the awareness level where most of the women were unaware of the condition and the means to prevent it. Later on, Ayesha and Khan, (2017) checked the level of awareness regarding osteoporosis and its prevention and reported that about 46 per cent of the women had knowledge regarding osteoporosis and measures to prevent it while majority (54%) were unaware. Level of awareness varied significantly with level of education (p=0.006). Urban dwellers were more aware about osteoporosis when compared to rural women (p=0.004). This study concluded that overall awareness about osteoporosis is low and

here is a need to have community based alertness campaigns regarding osteoporosis as it continues to be under recognized in many parts of India. Meanwhile, Al-Muraikhi *et al*. (2017) also observed that the overall knowledge of osteoporotic risk factors and preventive practices among women of reproductive age found to be 61.4 per cent and knowledge related to the components of risk factors being the lowest at 50 per cent. A statistically significant relation was noted between the overall knowledge score and age, level of education, marital status, and positive family history of osteoporosis. About 79 per cent of the participants recorded to be exposed to direct sun rays for more than 30 minutes per week while only 33.6 per cent of them found to be engaged in proper weight bearing exercises. Finally, the food consumption score noted to be low at 45.4 per cent, especially when it came to fruits and vegetables (39.6%). Another study to assess the knowledge, attitudes and practices about osteoporosis was conducted by Bilal *et al*. (2017) among 400 females (mean age 19.4± 1.2 years). Only 8.0 per cent scored good pertaining to knowledge about osteoporosis whereas majority of the respondents (49.0%) scored poor. Very less number of women (29%) found to be consuming calcium in adequate amounts as per RDA, exercise levels were insufficient in terms of duration and the type of exercise recommended to them. Only 12 per cent noted to be engaged in exercises while 5 per cent involved in definitive behaviors to improve their bone health.

Subsequently, Senthilraja *et al*. (2019) assessed the level of knowledge cross-sectionally of osteoporosis among 302 (mean age 58.5 ± 6 years) women in southern India using a validated questionnaire named as osteoporosis knowledge assessment tool (OKAT). Although, most of the subjects found to be aware of the consequences of osteoporosis and a generalized lack of awareness with regard to risk factors and available treatment options also seen. Overall, poor level of awareness seen among 60 per cent of the respondents which showed a gross deficit in awareness of osteoporosis in Indian postmenopausal women. Similarly, Kadam *et al*. (2019) conducted a cross-sectional study in 2080 apparently healthy adults aged 40-70 years to assess knowledge of osteoporosis and its risk factors using the revised osteoporosis knowledge test (OKT). Results showed that higher percentage (73%) of women knew about osteoporosis as a disease and could define it. Higher percentage of subjects with a family history of the condition (61%) noted to be aware of osteoporosis as a disease and could define it compared with 44 per cent who had no family history of the same. More than 60 per cent recognized the importance of at least 30 minutes of moderate exercise daily. Higher percentage (77%) of women could correctly identify sources of calcium and vitamin D. The scores for level of knowledge of osteoporosis expressed as percentage indicated that only 0.4-3.7 per cent showed a high level of knowledge, 12-33 per cent showed average knowledge, while the majority (>64%) of the respondents showed a low level of knowledge. Recently, Shaki *et al.* (2021) studied to determine the level of awareness in 2000 women aged 45-85 years in Guwahati, Northeastern part of India and noted the awareness level to be only 37.85 per cent. The proportion of women having prior knowledge regarding osteoporosis found to be significantly higher in educated women (up to XII standard & higher). Women with a previous fragility fracture in the family reported better awareness than those without such a history. Parameters like seriousness, advantage of taking calcium, exercise, no motivation to exercise, barriers to take calcium and health motivation noted to be associated with bone mineral density and statistically significant (0.421, 0.292, 0.383, 0.781, 0.855 and 0.873, respectively).

**Prevalence**

Women experience a marked increase in bone loss during pre menopause. Studies have shown that bone loss starts from the age of 30 to 40 years. Shatrugna *et al.* (2005) assessed the prevalence of osteoporosis and osteopenia among Inidan women aged between 30-60 years and revealed low bone mineral density and high rate of osteopenia (52%) and osteoporosis (29%). Similarly, majority of the women among 538 subjects found prevalent to osteoporosis (44.1%) and osteopenia (41.6%) as identified by Babu *et al*. (2009).

Another investigation done on 105 women aged 40 years and above found osteopenic (31.4%) and osteoporosis (14.3%) and result showed significant positive correlation between age and time since menopause and bone mineral density (Unni *et al.*, 2010). Later on, Aggarwal *et al.* (2011) also reported high rates of osteoporosis in premenopausal women (53%) residing in Chandigarh. A study on 158 females with mean age of 42.5 years reported to be osteoporotic (13.3%) and osteopenic (48.1%), respectively (Agarwal and Verma, 2013)**.** Furthermore, an observational study carried out on 100 women (40-65 years) for a period of one year unveiled that more that half of the subjects aged 40-50 years found osteoporotic and osteopenic (65.7%) followed by 22.9 per cent subjects aged 51 to 59 years and 11.4 per cent aged above 60 years. Another investigator explained that 10.9 per cent and 62.2 per cent subjects categorized as osteoporotic and osteopenic, respectively (Das *et al*., 2016).

Singh and Paul (2017) conducted a cross sectional study among 316 pre and post-menopausal women of Allahabad to determine the bone mineral density screening using P-DEXA and the results indicated 26.58 per cent occurrence of osteoporosis followed by osteopenia (46.20%). Subsequently, Chawla *et al.* (2018) studied the prevalence of osteopenia in 141 females (mean age, 46.54 years) having BMI of 26.58 kg/m² found to be 36 per cent, osteoporosis (4%). Congruently, one more cross-sectional research conducted on 152 females aged between 35 to 65 years in Allahabad district and it concluded that the prevalence of osteoporosis and osteopenia recorded to be 11.2 and 58.9 per cent, respectively (Sharma and Paul, 2018).

An observational study determined by Chaudhary *et al.* (2019) on 45 to 50 years old 3287 women specifically selected from nine districts of Vidarbha region in Maharashtra. The result signified that the overall predominance of osteoporosis and osteopenia observed as 43.33 and 55.2 per cent, respectively. Similarly, Jagiasi and Bochare, (2019) also surveyed the premenopausal women to assess the predominance of osteoporosis and osteopenia among them in Maharashtra. Majority of the women found osteopenic (58.06%) followed by osteoporotic (14.54%) as per records. Furthermore, Ganji *et al.* (2019) concluded that the occurrence of osteoporosis in premenopausal women suffering from celiac disease noted to be 14.4 per cent and osteopenia (39.6%).

The prevalence of osteoporosis is not only higher in Asian countries like India as compared to western the deterioration in bone health also tends to present itself at a relatively younger age.

**Role of nutrients**

Bone is a nutritionally modified tissue and diet has a significant influence on its health. Eating a diet rich in calcium and ensuring that people are not vitamin D and protein deficient offers tremendous opportunities to improve bone and muscle health and reduce the risk of osteoporosis (Khadilkar and Mandlik, 2015). The current studies on osteoporosis focus on awareness of the importance of maintaining sufficient daily levels of calcium, vitamin D and proteins together with physical activity to maintain bone health at all ages (Kim and Lee, 2016). Calcium is absorbed in the small intestine both by passive diffusion and by active absorption regulated by vitamin D (Hejazi *et al.,* 2020). The modified lifestyle can reduce the risk of osteoporosis and osteoporotic fractures. It involves healthy diet, active lifestyle, regular exercise and prevention from fall, sudden strain or bumps. Balanced diet and adequate nutrition plays an important role in prevention and treatment of osteoporosis. Several nutrients, including magnesium, potassium, Vitamin C, vitamin K, several B vitamins, carotenoids and food constituents like diary, fruits and vegetables has emerged as important modifiable protective factors for bone health (Al-Khammash *et al*., 2021).

**Calcium**

Everybody needs calcium for a healthy body, bones and teeth. Most of the calcium is absorbed through a good diet and natural sunlight but bone density and strength reduces with age which can lead to osteoporosis or brittle bone disease. So, calcium is needed for maintaining good health. It is naturally found in some foods and is supplemented to others.

The body builds new bones faster than it breaks down old bones in children and adolescents. So, the total bone mass increases and this continues until about age 30. But in older adults, especially in menopausal women, bone is broken down at faster rate than is built and if calcium intake is too low then the problem of osteoporosis can arise. The best way to get enough calcium on a daily basis is by consuming variety of healthy foods from all the different food groups to fulfill the recommended requirement which is 800 mg/day (ICMR, 2020). However, when a woman is closer to menopausal stage, the risk of developing osteoporosis can be minimized by increasing dietary calcium intake and aim for consuming 1300 mg of dietary calcium per day which is equal to about three to four servings of dairy food (Better Health Channel, 2019). The direct correlation between calcium intake and prevention of osteoporosis is limited but there are several researches which signify the role of dairy and non-dairy food and food products in the preclusion of fractures in different sites. Sahni *et al.* (2014) evaluated the association of dairy products with incident of hip fracture on 830 men and women and reported that greater intake of milk and milk products plus yogurt lowered the risk for hip fracture in older adults.

Bone mineral mass, geometry and microstructure, hence determinants of fracture risk, result bone accrual during growth and bone loss later in life. Peak bone mass, which is reached by the end of the second decade of life, is mainly determined by genetic factors. Among other factors influencing bone capital, dietary intakes, particularly calcium and protein, play a significant role in peak bone mass attainment. Various intervention trials have shown some beneficial effects of dairy products on bone capital accumulation during growth and on bone turnover in adults (Munoz-Garach *et al.,* 2020). Intake of dairy products particularly the fermented ones which also provide probiotics in addition to minerals appear to be associated with lower risk of fractures. In controlled intervention trials, milk ultra filtrate calcium supplements increased peripheral skeleton bone mineral content in both pre-pubertal girls and boys. These effects are attributed to lower bone turnover (Munoz-Garach *et al.,* 2020). Dairy products provide about 50–60 per cent of calcium intake during growth. Avoidance of dairy products in initial ages of life may increase the risk for fracture in later life. In this regard, Melaku *et al*. (2016) identified that prudent dietary pattern characterized by high intake of fruits, vegetables, sugar, nut based milk, fish, legumes and bread found to be positively associated with lower prevalence of low bone mineral density as compared to the western dietary pattern characterized by high levels of processed and red meat, snacks, take away foods, jam, beer, soft drinks, poultry, white bread, potato, high-fat dairy products and eggs. Similarly, Shin *et al.* (2017) also revealed that consumption of milk-cereal and whole grain dietary pattern found to be positively associated with increase intake of calcium and participants found to have less chances of having low bone mineral density.

**Phosphorus**

Phosphorus is an essential micronutrient with various physiological roles. It is a component of nucleic acids, high-energy compounds (e.g., ATP, ADP, GTP, GDP), phospholipids and biological membranes, which plays an important role in energy metabolism, intracellular cell signaling and acid-base balance (Butusov and Jernelov, 2013). Phosphorus can be found in foods in naturally occurring forms, such as meat, dairy products, cereals, seeds, nuts, legumes as well as in inorganic phosphate additives, which can be used for various purposes in food processing (Vorland *et al*., 2017). Phosphorus is the second basic component (after Ca) of bone tissue. The human body contains 550–770 grams of phosphorus of which almost 85 per cent is stored in teeth and bones in the form of phosphoproteins and hydroxyapatite crystals (Ciosek et al., 2021). Phosphorus deficiency causes sluggish growth and rickets in children and osteomalacia in adults. Lack of phosphorus in the diet is very rare in humans due to its natural occurrence in large amounts of food and also the body's high ability to absorb it. In healthy adults, the current RDA for phosphorus is 700 mg/day and 1250 mg/day during adolescent growth (Vorland *et al*., 2017).

Lee *et al*. (2014) observed the association between dietary calcium and phosphorus intakes, dietary calcium phosphorus ratio and bone mass in 4,935 participants (2,309 men and 2,626 women) aged more than 20 years. Dietary calcium intake and dietary calcium/phosphorus ratio found positively related to bone mass density for femoral neck in men ($\geq$ 50 years of age) and dietary calcium intake showed positive association with bone mass density for whole body in premenopausal women. Lee and Cho, (2015) also concluded that increased intake of phosphorus was associated with an improvement of 4.2 per cent in bone mineral content, 2.1 per cent in bone mineral density and reduced risk of osteoporosis by 45 per cent in adult individuals whose calcium and phosphorus supplementation was within normal limits.

**Vitamin D**

Vitamin D deficiency is a global public health problem so it is necessary to maintain an adequate intake of vitamin D as it enhances intestinal absorption of calcium and phosphate and low concentrations of vitamin D are associated with impaired calcium absorption, negative calcium balance and a compensatory rise in parathyroid hormone which results in excessive bone resorption (Khadilkar and Mandlik, 2015). It is synthesized in the human skin upon exposure to sunlight. Although India has abundant sunlight, several reports state that Indians suffer from vitamin D deficiency which may be due to low sun exposure, traditional clothing (*saris, salwar kameez*), inadequate dietary intake, poor vitamin D fortification of food and highly pigmented skin (Aparna *et al*, 2018). A study also conducted to assess the effect of clothing on vitamin D status, bone turnover markers and bone mineral density in pre menopausal women aged 20 to 35 years. The respondents were divided into three groups on the basis of their clothing style i.e. control unveiled, *hejab* and veiled groups. Finding reveal that low vitamin D levels observed among hejab and veiled participants and therefore, it is concluded that clothing style may contribute to vitamin D deficiency.

There is epidemiological evidence that higher serum vitamin D levels are associated with a greater bone mineral density in both young and old populations with a linear relationship maintained up to a serum vitamin D level of approximately 75 nmol/l (Hill and Aspray, 2017). A correlated study done on respondents aged 2 to 12 years reflected that supplementation of oral vitamin D (1000 IU) and calcium (500 mg) per day for a period of one year improved bone mineral content in children (Thiagarajan *et al.*, 2019). Similarly, another clinical trial done on 400 patients aged 30 to 60 years with vitamin D deficiency treated continuously with vitamin D capsules (50,000 IU) per week for eight weeks. At the end of the treatment period, all subjects were evaluated for bone density and the results showed significant improvement in bone density indices (Shahnazari *et al.*, 2019). Furthermore, an investigation done to assess the effect of calcium and cholecalceferol treatment on hip fractures in elderly women for three years showed that daily supplementation of 1000 to 2000 mg calcium along with 800 IU of cholecalceferol during the trial period substantially decreased the risk of hip fracture and other non vertebral fractures in elderly women living in nursing homes (Reid and Bolland 2020). Kwon *et al.* (2020) determined the effect of supplementation of vitamin D on bone mineral density in 187 osteoporotic patients. The patients were divided in four groups and different amounts of vitamin D (0, 400, 800 and ≥ 1000 IU) given to each group per day. Result unveiled that supplementation of ≥ 1000 IU of vitamin D per day increased bone mineral density in lumbar spine region.

**Protein**

Protein is a building block for strong bones and muscles and low protein intake is associated with reduction of muscle mass across the life span. Insufficient protein intake is detrimental to bone development and bone mass maintenance and prevention of osteoporosis.

Though, the range of protein intake for optimizing bone health among premenopausal women is unclear. But, there are several investigations which show the association of protein intake with improved bone health. Relatively, a randomized controlled trial done on 90 premenopausal women aged 19-45 years divided into three groups different calorie-restricted diets given to them for 16 weeks containing high protein (30% of total energy), high dairy (15% of energy from protein), high calcium (1600 mg/day); adequate protein (15%), medium dairy (7.5%), medium calcium (1000 mg/day); and adequate protein (15%), low dairy (<2%), low calcium (<500 mg/day). The group who consumed high dairy foods, dietary protein, and calcium significantly increased their bone formation markers (osteocalcin and procollagen 1 amino-terminal propeptide), increased 25-hydroxy vitamin D levels, decreased parathyroid hormone levels, and did not change levels of bone resorption markers (Josse *et al.*, 2012). Similarly, a meta- analysis done to identify the relationship between dietary protein consumption and risk of fractures which proved a statistical significant difference as the higher intake of total dietary protein decreased hip fractures to 11 per cent (Wu *et al*., 2015). Later on, Shamms-White *et al.* (2017) found positive associations between high versus low protein intakes and bone mineral density or bone mineral content for nearly all bone sites and statistical significant differences observed at lumbar spine region.

Furthermore, Hill *et al.* (2019) conducted a randomized, controlled, double-blind study on 380 non-malnourished older participants (≥ 65 years) by supplementing vitamin D, calcium and leucine-enriched whey protein drink for a period of 13 weeks. Result showed a small (0.02 g/cm$^2$; ~ 2%) but significant increase in total bone mineral density in the active group after supplementation ($p = 0.033$ vs. control). It improved active form of vitamin D [25(OH) D], suppressed parathyroid hormone which indicated better bone health. Likewise, another researcher also examined the effect of protein intake on bone mineral density at different body sites for a period of two years and found that increment in protein intake (25% of total energy from protein) per day is positively associated with increase in bone mineral density (Tsagari, 2020).

**Magnesium**

Magnesium is an essential micronutrient with a wide range of metabolic, regulatory and structural functions. It is the basis for ATP, regulates the activity of about 300 enzymes involved in the synthesis of proteins, carbohydrates and nucleic acids and also maintains normal neuromuscular function (Castiglioni *et al.*, 2013). Magnesium also antagonizes calcium and potassium when it is absorbed in the small intestine, and chronically low levels of calcium and potassium may be related to the underlying magnesium deficiency. Bones store about 60 per cent of total body magnesium, approximately 30 per cent is present in muscles, 9 per cent in soft tissues and 1 per cent is found in extracellular fluids. One third of skeletal magnesium is located in the cortical bone on the surface of hydroxyapatite crystals and in the areas around them. Magesium is important for bone development as it stimulates bone formation and is also essential for bone mineralization (Ciosek *et al.*, 2021). Excessive intake of alcohol and coffee, inappropriate diet, stress and various diseases such as diabetes, heart failure, hypertension and postmenopausal osteoporosis can also adversely influence the content of magnesium in the body (Martiniakova *et al.*, 2022).

With regard to the serum concentration of magnesium, most of the studies focus on postmenopausal women. In this regard, Okyay *et al*. (2013) assessed the relationship between the serum concentrations of magnesium and the presence of osteoporosis by enrolling 728 women and dividing them into two groups according to the presence or absence of osteoporosis. Result highlighted a significant association between low serum magnesium values and the presence of both lumbar (L1-L4) and femoral bone mineral density. It showed that 47.1 per cent of osteoporotic women at the level of L1-L4, 29.4 per cent of osteoporotic women at the level of the whole femur and 32.4 per cent of osteoporotic women at the neck of the femur have lower serum magnesium value than the reference range. Conversely, Orchard *et al.* (2014) reported a decreased whole body and hip bone mineral density in postmenopausal women with lower daily magnesium intake. However, no relationship between low magnesium supplementation and increased risk of fractures was determined in their study. Sharma *et al*. (2016) observed that serum magnesium in women with osteoporosis ($1.95 \pm 0.44$ mg/dl) was significantly lower than women with osteopenia ($2.22 \pm 0.42$ mg/dl), however, remaining within the reference ranges (1.9–2.5 mg/dl). Rai and Sharma, (2016) done study on 68 women, including 33 osteoporotic and 35 with osteopenia and observed that the serum magnesium concentration was lower in the osteoporotic group ($1.95 \pm 0.44$ mg/dl) compared with osteopenic women ($2.22 \pm 0.42$ mg/dl) in a statistically significant way. Later on, Mederle *et al.* (2018) investigated the correlation between bone mineral density and serum magnesium levels in 132 post-menopausal osteoporotic women compared with 81 healthy (non-osteoporotic) women. Osteoporotic women showed significantly lower concentrations of serum magnesium compared to the control group ($1.76 \pm 0.06$ mg/dl compared to $2.14 \pm 0.14$ mg/dl). Serum magnesium levels were positively correlated with bone mineral density.

**Other nutrients**

The process of bone formation requires an adequate and constant supply of various nutrients such as calcium, protein and vitamin D. However, there are several other vitamins and minerals needed for metabolic processes related to bone including manganese, potassium, zinc, vitamin K, vitamin C etc.

Manganese (Mn) is a metal element present both naturally and as a consequence of contamination of the soil, sediments and water; it can exist in different oxidation states, of which $Mn^{2+}$ and $Mn^{3+}$ are the most important from a biological point of view (Expert Group on Vitamins and Minerals, 2003). Manganese deficiency can lead to several adverse effects which include growth alterations, skeletal abnormalities, reproductive defects, ataxia, and lipid and carbohydrate metabolism defects (European Food Safety Authority, 2006).

**Potassium**

The most facilitated hypothesis regarding the benefit of dietary potassium on bone health is through its effect on acid-base balance even though the role of the skeleton in pH regulation is controversial (Hamm *et al.*, 2015).

Association of higher dietary potassium with an increase in total hip and femur neck bone mineral density in 3135 men aged >50 years and 4052 postmenopausal women was analyzed by Kong *et al*. (2017). Observation concludes that overall, the highest potassium intake group showed a significantly higher total hip and femur neck bone mineral density as compared to lower groups. Postmenopausal women in the highest potassium intake group showed considerably higher lumbar, total hip, and femur neck bone mineral density as compared to those in lower potassium intake groups indicating the beneficial effects of dietary potassium intake on bone health. In yet another similar study, Ha *et al.* (2020) conducted a cross-sectional study including 8,732 men and postmenopausal women over 50 years old. Result demonstrates that daily potassium intake was significantly related to a decreased risk of osteoporosis at the lumbar spine in postmenopausal women. However, the dietary potassium level was not related to the risk of osteoporosis in men suggesting that a higher dietary potassium level is positively associated with increased BMD and a decreased risk for osteoporosis in older women.

**Zinc**

Zinc is a cofactor in many metalloenzymes and is an extremely important element for bone health. Skeleton contains a large proportion of the total body burden of zinc. Zinc plays a pivotal role in the regulation of bone homeostasis. Many zinc-related proteins are found to involve in the regulation of cellular function in osteoblasts and osteoclasts. Zinc stimulates cell differentiation, cell proliferation, and mineralization in osteoblasts through gene expression of various proteins including type I collagen, alkaline phosphatase, and osteocalcin (Yamaguchi, 2010). Zinc is found in a wide variety of foods including red meat, lamb, shell fish, seeds, nuts, dairy products, poultry and beans and the recommended daily minimum intake of zinc is 17 and 13 mg per day for men and women respectively (ICMR, 2020).

Fung *et al.* 2013 studied the supplemental effect of zinc on bone density in forty-two subjects (10–30 years) and assigned 25 mg zinc per day or placebo. At the end of the intervention, plasma zinc level increased significantly in 11 subjects and the group assigned with zinc supplementation reported significantly greater increase in whole body bone mineral content. Roshan *et al.* (2015) suggest that low intake of dietary zinc than the recommended amount and its association with low bone density was observed in postmenopausal women. Nakano *et al.* (2021) investigated the efficacy and safety of zinc pharmacotherapy on 122 osteoporotic elderly patients with zinc deficiency for 12 months. In addition to standard therapy for osteoporosis in a clinical setting, the subjects received oral administration of 25 mg zinc twice a day. Zinc administration successfully shown to elevate serum zinc levels and increased bone mineral density. Bone formation markers rose markedly, whereas bone resorption markers displayed moderate or no characteristic changes suggesting that additive zinc supplementation may contribute to bone mineral density augmentation ensuring the prevention of occurrence of fracture in elderly osteoporotic patients with zinc deficiency.

**Vitamin K**

Vitamin K is a fat-soluble vitamin that occurs in two forms—as vitamin K1 (phylloquinone) and vitamin K2 (menaquinone). The first mentioned (K1) is the principal dietary form and can be achieved by consuming green vegetables, such as spinach, kale, broccoli, cauliflower, cabbage or supplements. The latter (K2) is produced by bacteria in the gut, but can also be found in fermented soy and dairy products (e.g., cheese), meat, fish, eggs, beef and pork liver. The current RDA is set at 90 µg/day for women and 120 µg/day for men (Dennehy and Tsourounis, 2010). Vitamin K regulates functions of osteocalcin, the most abundant non-collagenous protein within bone matrix, primarily produced by osteoblasts during their differentiation. Vitamin K2 is recognized as safe and effective in the treatment of age-related bone loss and osteoporosis. It is involved in modulating the RANK/RANKL signaling pathway by inhibiting RANKL and reducing osteoclastogenesis (Lacombe *et al.*, 2020).

The potential benefits of vitamin K2 supplementation for bone loss and BMD (mainly lumbar), especially in patients with osteoporosis, have been confirmed in several studies Kanellakis *et al.* (2012) observed the effect of dairy products enriched with calcium (800 mg), vitamin $D_3$ (10 µg), and phylloquinone (vitamin $K_1$) or menaquinone-7 (vitamin $K_2$) on parameters of bone metabolism in postmenopausal women following a 12-month intervention. The subjects were divided into three intervention groups and a control group (CG). Furthermore, in two of the three intervention groups the dairy products were also enriched with vitamin K, providing daily 100 µg of either phylloquinone or menaquinone-7. Result showed increase serum 25(OH)D levels in all intervention groups. Furthermore, both $K_1$ and $K_2$ groups had a significantly lower mean serum undercarboxylated osteocalcin to osteocalcin ratio and urine deoxypyridinoline levels at follow-up and significant increases in total-body bone mineral density were observed in all intervention groups while significant increases in lumbar spine bone mineral density were observed only for $K_1$ and $K_2$. Evenepoel *et al.* (2019) conducted a study on 30 individuals in three experimental phases for a period of four weeks which include high dietary vitamin K (group I), low dietary vitamin K (group II) and control (group III). Findings revealed that respondents of group I consuming high dietary vitamin K showed significant improvement in bone metabolism by enhancing osteoblast and osteocalcin levels.

**Vitamin C**

Vitamin C (ascorbic acid) is a water-soluble essential vitamin required for many physiological processes including biosynthesis of collagen, L-carnitine, hydroxyproline, hydroxylysine, several hormones (e.g., noradrenaline/adrenaline, peptide hormones), gene transcription, regulation of translation and elimination of tyrosine. Taking into account the bone, it is an essential cofactor not only for collagen production but also for osteoblast synthesis and differentiation and also has the ability to suppress osteoclast differentiation (Aghajanian *et al*., 2015). Vitamin C deficiency can lead to scurvy, which is manifested by osteolysis, osteonecrosis, decreased BMD, bone pain, impaired wound healing and pathological fractures. Scurvy can eventually manifest as osteoporosis (Brzezińska *et al.*, 2020). According to Doseděl *et al.* (2021), "Deficiency of vitamin C is associated with improper collagen synthesis, inappropriate osteoid formation and increased bone resorption". Kim *et al*. (2016) in a study sample comprising 3,047 subjects for a period of four years indicated a positive association that higher vitamin C intake levels was correlated with a lower risk of osteoporosis in adult women aged 50 and above with low levels of physical activity. However, no association was seen between vitamin C intake and osteoporosis risk in those with high physical activity levels.

**CONCLUSION**

In recent times, osteoporosis is becoming a life threatening health issue in all ages owing to its increased fracture risk and with the problem being that it is often under recognized and untreated. People at high risk for fractures do not get enough evaluation for the disease or get suitable treatment due to lack of awareness in most of the population. Modified lifestyle involving healthy diet, active lifestyle, regular exercise and prevention from fall, sudden strain or bumps can reduce the risk of osteoporosis and osteoporotic fractures. Balanced diet and adequate nutrition plays an important role in prevention and treatment of osteoporosis. Apart from calcium, vitamin D, phosphorus and protein, several other nutrients, including magnesium, potassium, Vitamin C, vitamin K, several B vitamins, carotenoids and food constituents like diary, fruits and vegetables has emerged as important modifiable protective factors for bone health.

**CONFLICT OF INTEREST**

None

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